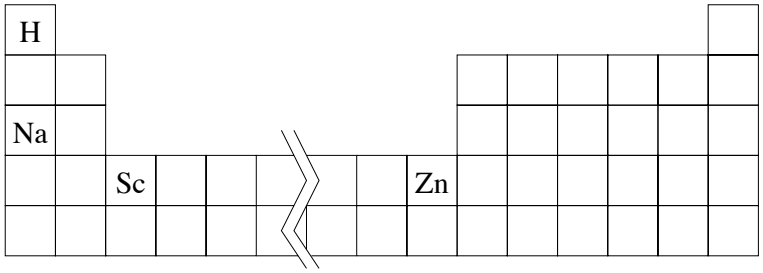
Atomic Structure Revision Problems

Rhys Davies, St. Catherine's College, 2009

1. An outline of the periodic table of the elements is shown below. Give the complete electronic configuration of scandium (Sc). How many elements are there in the series between scandium and zinc (Zn) inclusive?



   (a) Sodium (Na) atoms are put into the excited state in which the outer electron is in the 4p configuration. Draw a diagram that shows all the allowed transitions by which these atoms cascade down to the ground state.

   (b) The ionisation energy of sodium is 5.14eV. Following excitation to the 4p configuration, the shortest wavelength radiation observed is $\lambda = 330$nm. Estimate the quantum defects for s and p states in sodium.

   (c) When the fine structure is resolved, identify which of the lines in your answer to part (a) are singlets, doublets or higher multiplicities.

2. State the selection rules for electric dipole transitions between states for which LS-coupling is appropriate. Where possible, give simple physical arguments justifying these selection rules.

   Which of the following transitions obey the electric dipole selection rules? For those which don't, give the reason:

$$
\begin{aligned}
(i) \quad & 1s^2 2p\ {}^2P_{\frac{3}{2}} \rightarrow 1s^2 2s\ {}^2S_{\frac{1}{2}} \\
(ii) \quad & 1s2s3p\ {}^4P_{\frac{1}{2}} \rightarrow 1s2s^2\ {}^2S_{\frac{1}{2}} \\
(iii) \quad & 1s^2 2p3d\ {}^1P_1 \rightarrow 1s^2 2p3s\ {}^1P_1 \\
(iv) \quad & 1s^2 2p3d\ {}^3D_2 \rightarrow 1s^2 2p^2\ {}^3D_1 \\
(v) \quad & 1s^2 2s4s\ {}^1S_0 \rightarrow 1s^2 2s2p\ {}^1P_1
\end{aligned}
$$

3. One of the important features of heavy atoms is their x-ray spectra. Here we consider tungsten (Z = 74) and platinum (Z=78).

   (a) When tungsten is bombarded with high-energy electrons, the resulting x-ray spectrum shows a continuum with distinct peaks superimposed. Explain the physics which produces these features.

   (b) Give a formula modelling the energies corresponding to the peaks described above.
   The wavelengths of the first two K-series lines for tungsten are K_α = 2.10 x 10^{-11}m, K_β = 1.84 x 10^{-11}m, and they only appear when the incoming electrons have an energy corresponding to at least 1.78 x 10^{-11}m. Use this data to estimate the values of any parameters in your formula.
   Use your formula to predict the wavelengths of the K_α and K_β lines for platinum. Compare this to the measured values of K_α = 1.88 x 10^{-11}m, K_β = 1.64 x 10^{-11}m and comment on the result.

   (c) Suppose that instead of a K_α x-ray, an Auger electron is ejected from the L-shell (in Tungsten). Derive an estimate for the kinetic energy of this electron.